AF/

Docket No.: 392.1681

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Atsushi WATANABE, et al.

Serial No. 09/546,392 Group Art Unit: 2623

Confirmation No. 2369

Filed: April 10, 2000 Examiner: Craig W. Kronenthal

For: ROBOT SYSTEM HAVING IMAGE PROCESSING FUNCTION

APPELLANT'S BRIEF UNDER 37 C.F.R. § 41.37

Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Sir:

In a Notice of Appeal filed June 20, 2005, the applicants appealed the Examiner's January 18, 2005, Office Action finally rejecting claims 1-32. Therefore, Appellant's Brief is due August 18, 2005. Appellant's Brief together with the requisite fee set forth in 37 CFR § 41.20, is submitted herewith.

I. REAL PARTY IN INTEREST

The real party in interest is FANUC LTD, the assignee of the subject application.

II. RELATED APPEALS AND INTERFERENCES

Appellant, appellant's legal representative, and the assignee do not know of any prior or pending appeals, interferences or judicial proceedings which may be related to, directly affect or be directly affected by, or have a bearing on, the Board's decision in this appeal.

III. STATUS OF CLAIMS

Appealed claims 1-32 have been rejected and are on appeal.

IV. STATUS OF AMENDMENTS

No amendments have been filed subsequent to the final rejection made on January 18, 2005. The Appellant's did submit a Request for Reconsideration and Clarification of Rejection under 37 CFR § 1.116 that was filed April 13, 2005 and was considered by the Examiner as indicated by the Advisory Action mailed May 20, 2005.

V. SUMMARY OF CLAIMED SUBJECT MATTER

Independent claim 1 recites a robot system having an image processing function for determining orientation, or orientation and position of a robot operation on one of a plurality of objects W.

Claim 1 further recites a robot (e.g. robot RB in Fig. 1) and a first image capturing device 21 capturing image data of the plurality of objects W containing respective images of the objects W (Fig. 1, p. 5, ll. 20-22). A memory 2 storing reference models (Fig. 3, p. 6, ll. 25-26), each comprising an image of a reference object captured by the image capturing device 21 in a different direction (Figs. 2a-2d, p. 12, ll. 9-11), and for each reference model storing information of the capturing direction of its associated image and information of an orientation of the robot RB with respect to the reference object (Fig. 5, p. 13, ll. 14-19), the information of the capturing direction representing a rotational posture of the reference object relative to the robot, the reference object being one of the plurality of objects or an object having a shape identical to that of one of the plurality of objects W (p. 11, ll. 24-26).

Claim 1 further recites a processor 31 (Fig. 4) to perform matching on the image data containing images of the plurality of objects captured by the first image capturing device (p. 11, ll. 8-14) with each of the reference models successively to select one object having an image matched with one of the reference models, and to determine orientation, or orientation and position of the robot RB operation based on the image of the selected one object, based on the one reference model and the information of its associated capturing direction, and based on the information of the orientation of the robot RB operation with respect to the reference object that is associated with said one reference model (p. 8, ll. 10-14).

Independent claim 12 is directed to a robot system having an image processing function for determining orientation and recites features that are similar to claim 1 and which are supported by the specification in a similar manner.

Independent claim 23 is directed to a method for automatically determining an arrangement of a workpiece relative to a robot performing a method as described above with respect to claim 1.

None of the claims contain an element expressed as a means or step for performing a

specified function without the recital of structure, material, or acts in support thereof.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Claims 1, 12 and 23 stand rejected under 35 U.S.C. §102(b) as being anticipated by Spight (US 4,462,046).

VII. ARGUMENT

A. Review of the Prior Art

i. U.S. Patent No. 4,462,046 ("Spight")

Spight discloses a machine vision system utilizing programmable optical parallel processing. The scene being viewed by the vision system of Spight has been monitored by a video camera and converted into an electrical signal which produces an optical image on a object reproduction display 10. Simultaneously, a reference display indicative of a desired object to be identified is displayed on a reference display 12 from data stored within a memory of the system control processor. Spight, 3:29-3:38.

One embodiment of Spight would allow the incoherent optical to electrical converters 52 to view a single perspective of the object Ob being viewed. Instead of iterating possible particular configurations of the object by viewing the object from various positions, a plurality of configurations of each desired object to be identified would be stored within the system control processor 64. For each iteration of the parallel optical processing of Spight, a new reference signal would be provided. Each desired object to be identified would be defined by a plurality of reference signals indicative of a number of particular orientations of the object being viewed. Thus, a plurality of iterations could be performed without the need to vary the apparent perspective of the scene viewed by the incoherent optical to electrical converters 52. Alternatively, the plurality of reference signals could be produced by computer generated rotation of translation images of each object to be identified. Spight, 4:1-4:19.

The convolution of the object signal produced by the object display 10 and the reference signal produced by the reference display 12 is applied to a video detector 40 arranged at the focal distance of the inverse Fourier transform lens 36. This video detector may be a video camera or, alternatively, a charge coupled device (CCD) array. Thus, the object signal is correlated with the reference signal in a manner which is utilized by the remainder of the system as explained in conjunction with FIG. 2. Spight, 5:42-5:51.

The objects Ob to be viewed by the vision system of Spight may be arranged randomly on a viewing table 50. Spight, 6:11-6:13.

This cross-correlated Fourier transform signal .phi.(x,y)* IR(x,y) is applied to a correlated

signal optical to electrical converter 60 including video detector 40. The electrical correlation output of the correlated signal optical to electrical converter 60 is then processed by the system control processor 64 in a known manner in order to determine the degree of correlation between the object signal o(x,y) and reference signal r(x,y). When the degree of correlation between these respective signals exceeds a predetermined limit, the particular configuration then viewed by the incoherent optical to electrical converters 52 and their associated multiplexing interface 54 is determined to be closely associated with the reference signal indicative of the desired object to be identified recalled from memory within the system control processor 64. A high degree of correlation informs the system control processor 64 that the scene being viewed is closely approximated by the computer reproduced reference scene. Thus, it is possible to both identify the objects being viewed Ob and determine their location and spatial orientation via the parallel optical correlation utilized in Spight. Spight, 7:28-7:49.

The system of Spight, as controlled by the system control processor 64, thus repeatedly correlates a multiplicity of particular configurations of the object being viewed Ob with the reference signal indicative of a desired object to be identified to determine the correlation therebetween. If all configurations of orientation and position have been correlated with the reference signal and an insufficient correlation therebetween is discovered, the system control processor 64 may then recall a new data set indicative of a new desired object to be identified and thus a new reference signal for successive iterative comparison with particular configurations monitored by the incoherent optical to electrical converters 52 and their associated multiplexing interface 54. Thus, it is possible for the system of Spight to correlate a plurality of possible orientations of an object with a plurality of reference signals representative of desired objects to be identified in order to determine what object is being viewed and its position and orientation in space. Spight, 7:64-8:15.

Once the object is identified, the system control processor 64 provides this information and object position information to an effector control processor 200 which may drive a robotic effector or manipulator 202 to perform any desired task on the object being viewed. The position of the object is determined on the basis of the position of the bright points 212 viewed by the video detector 40. Because of the use of parallel optical processing which facilitates rapid iterations of the correlation between particular configurations of the object being viewed and the reference signals indicative of the object to be identified, the system of Spight may identify the

object, its location and orientation in a substantially real-time manner. Thus, even objects Ob moving along a conveyor line may be detected by the vision system of Spight and identified with an understanding of the object's location and orientation in sufficient time to perform a manipulative operation on the object via robotic effector 202 before the object is shifted, to any great extent, by the conveyor. Spight, 8:16-8:37.

This monitoring and evaluation of the correlation signal may be performed in order to evaluate the degree of correlation between the reference view information indicative of the desired object to be identified and the object or scene being viewed. If sufficient correlation exists (S13), the system control processor 64 in connection with the effector control processor 200 control the robotic effector 202 based on the reference view information being considered (S15). If no sufficient correlation exists, then the system control processor may either increment the reference view information, or alternatively change the angle the object is being viewed from, by controlling the signals received from the incoherent optical to electrical converter 62 by the multiplexing interface 54 (S14). Depending upon the embodiment for which the system control processor is programmed, one of these parameters will be incremented in order to iteratively cross-correlate new combinations of reference view information and information indicative of objects being viewed. Thus, the correlation program is again initiated. Spight, 9:59-10:11.

If a high degree of correlation exists, the system control processor 64 provides the effector control processor 200 with information related to the identification, spatial orientation, and position of the object being viewed, this information being derived from the information related to the desired object to be identified or reference information produced within the system control processor. If a high degree of correlation is not obtained from the correlation of the object signal and reference signal, the system control processor either compares the same object signal with a new reference signal or compares the same reference signal with a new object signal in order to iteratively correlate information related to a desired object to be identified stored within the system control processor 64 with information related to the scene being viewed or reference object positioned on the viewing table 50. Spight, 11:21-11:37.

B. Claims 1, 12 and 23 are patentable over U.S. 4,462,046 ("Spight")

In the final Office Action, the Examiner rejected independent claims 1, 12 and 23 as being anticipated by Spight. As these claims stand or fall together, the Appellant's argument is

focused solely on the rejection of claim 1.

i. Spight does not disclose (1) the same image capturing device capturing both image data of objects and images of reference models or (2) storing a capturing direction of the reference image and information of an orientation of the robot with respect to the reference object

Claim 1 recites: "a first image capturing device capturing image data of the plurality of objects containing respective images of the objects." Claim 1 also recites "a memory storing reference models, each comprising an image of a reference object captured by said image capturing device in a different direction". Because the same image capture device has been used, matching and orientation determination may become simple and accurate.

The Spight reference does not provide any explanation of how to derive its configuration data (in memory) used go generate reference signals. A fundamental feature of Spight is that "system control processor 64 recalls from its memory data indicative of a reference object or desired object to be identified." Spight, 6:41-6:44. Spight also discloses, "the scene being viewed is closely approximated by the computer reproduced reference scene." Spight, 7:44-7:46. Further, in Spight, "the system control processor 64 recalls reference view information from memory located in the system control processor 64." Spight, 9:29-9:31. Spight stores data in memory that can be converted to an optical signal for optical correlation processing. However, Spight does not disclose or suggest how the reference data is obtained. The only teaching in Spight is that "the plurality of reference of signals could be produced by computer generated rotation of translation images of each object to be identified." Spight, 9:17-9:19.

Spight discloses only two teachings about reference data in computer memory.

First, Spight generally discloses, "a plurality of configurations of each desired object would be stored in the system control processor 64." Spight, 9:6-9:8. Each configuration would be used to generate a corresponding reference signal. Spight, 9:10-9:13. However, in this first teaching Spight is completely silent on (1) how the configurations are obtained, and on (2) storing a capturing direction of the reference image and information of an orientation of the robot with respect to the reference object.

The Appellant respectfully submits that Spight does not disclose or suggest using the same capture device for both capturing reference images and for capturing an image of the object whose identify and location is to be determined.

The Appellant further submits that Spight does not disclose storing "information of the capturing direction of its associated image and information of an orientation of the robot with respect to the reference object," which "represents a rotational posture of the reference object relative to the robot" as is recited in claim 1.

Second, Spight discloses only one technique for deriving the configuration data or reference data stored in memory (the source of the reference signals). In Spight, the reference signals are produced by "computer generated rotation of the translation images of each object to be identified" (e.g. CAD-generated data). Spight, 9:16-9:19. This clearly does not meet the recitations of claim 1 mentioned above. Furthermore, this use of computer-generated reference data (e.g. CAD-generated data) suggests that Spight can operate without using information of the capturing direction of an associated reference image and information of an orientation of the robot with respect to the reference object relative to the robot. Spight does not disclose details of reference models/images as discussed above with reference to claim 1.

Claim 12 recites features similar to claim 1.

Claim 23 recites "storing reference images corresponding to images of the workpiece or an object so shaped (workpiece/object) and reference arrangement information indicating arrangements of the robot and workpiece/object relative to each other when the images were captured, the reference arrangements comprising rotational arrangements of the workpiece relative to the robot". As discussed above, Spight does not discuss or suggest how configurations are derived. Spight only mentions that the configurations are stored without explaining what a configuration entails or how it is obtained. Again, the reference must disclose the same level of detail as recited in the claim.

ii. Spight does not disclose determining the orientation of the robot operation

Claim 1 recites determining orientation of a robot operation based on the image of the object, the reference model, etc. In contrast, nowhere does Spight disclose or suggest determining the actual orientation of a robot operation. Spight discloses:

> Once the object is identified, the system control processor 64 provides this [identity] information and object position information to an effector control processor 200 which may drive a robotic

> effector or manipulator 202 to perform any desired task on the object being viewed. Position of the object is determined on the basis of the position of the bright points 212 viewed by the video detector 40. Because of the use of parallel optical processing which facilitates rapid iterations of the correlation between particular configurations of the object being viewed and the reference signals indicative of the object to be identified, the system of the present invention may identify the object, its location and orientation in an extremely fast, substantially real-time manner. Thus, even objects Ob moving along a conveyor line may be detected by the vision system of the present invention and identified with an understanding of the object's location and orientation in sufficient time to perform a manipulative operation on the object via robotic effector 202 before the object is shifted, to any great extent, by the conveyor. Spight, 8:16-8:37.

Spight does not disclose providing object orientation information to the effector or manipulator 202. Even if Spight did provide this information, it has no teaching or suggestion of determining the orientation of a robot operation. There is no indication that orientation can even be used. Spight may use robot graspers such as suction cups or other types of graspers that do not require orientation. Orientation information, if used at all, may be used to determine which type of robot hand to use, whether grasping is possible at all, whether the object needs to be agitated or otherwise moved for purpose of being grasped, and so on. As mentioned above, an anticipatory reference must disclose the same level of detail as found in the claims. The claims recite determining the orientation (or orientation and position) of the robot operation. Spight does not disclose this detail and only explicitly discloses providing object position information to the effector control processor 200.

iii. Spight lacks a processor to perform matching

Claim 1 recites "a processor to perform matching on the image data ... with each of said reference models." The rejection under appeal compares the processor to the computer 64 in Spight. However, the computer 64 in Spight does not actually perform matching on image data

with reference models. In Spight, correlation is performed by optical parallel processing. Correlation is by "an optical lens system" and "use of another optical lens in order to produce a cross-correlation of the viewed scene and a desired object". Spight, 2:53-3:1. Spight does disclose a processor 64, but this processor does not perform matching. Rather, the processor 64 evaluates the degree/level of optically-found correlation/matching as indicated by the optical correlation output. "The system control processor then monitors the degree of correlation..." Spight, 3:4-3:6. The processor 64 only evaluates the degree of correlation, which is not the same as performing matching itself. This difference is notable.

The type of optical system taught by Spight is expensive and inflexible. Furthermore, optical systems using lenses, splitters, and the like are not readily combined with digital systems. Therefore, one skilled in the art would find it difficult to combine Spight with non-optical systems.

C. Conclusion

In summary, the Appellant submits that claims 1-32 patentably distinguish over the prior art. Reversal of the Examiner's rejection is respectfully requested.

Respectfully submitted,

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VIII. CLAIMS APPENDIX

1. (PREVIOUSLY PRESENTED) A robot system having an image processing function for determining orientation, or orientation and position of a robot operation on one of a plurality of objects, the system comprising:

a robot;

a first image capturing device capturing image data of the plurality of objects containing respective images of the objects;

a memory storing reference models, each comprising an image of a reference object captured by said image capturing device in a different direction, and for each reference model storing information of the capturing direction of its associated image and information of an orientation of the robot with respect to the reference object, the information of the capturing direction representing a rotational posture of the reference object relative to the robot, said reference object being one of the plurality of objects or an object having a shape identical to that of one of the plurality of objects; and

a processor to perform matching on the image data containing images of the plurality of objects captured by said first image capturing device with each of said reference models successively to select one object having an image matched with one of said reference models, and to determine orientation, or orientation and position of the robot operation based on the image of the selected one object, based on said one reference model and the information of its associated capturing direction, and based on the information of the orientation of the robot operation with respect to the reference object that is associated with said one reference model.

2. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 1, wherein said reference models are obtained from a part of the image data of the reference object.

3. (ORIGINAL) A robot system having an image processing function according to claim 1, wherein said reference models are obtained by processing the image data of the reference object.

4. (ORIGINAL) A robot system having an image processing function according to claim 1, wherein said first image capturing device comprises a camera for capturing two-dimensional image data.

5. (ORIGINAL) A robot system having an image processing function according to claim 4, wherein said image data of the reference object are captured by said camera from a predetermined distance.

6. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 1, further comprising:

a second image capturing device; wherein

said robot situates said second image data capturing device to have said determined orientation or to have said determined orientation and said determined position with respect to the selected one object, and wherein

said processor processes second image data captured by said second image capturing device to detect position and/or rotational posture of the selected one object with respect to said second image data capturing device.

7. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 1 further comprising:

a second image capturing device for obtaining three-dimensional position; wherein

said robot situates said second image data capturing device to have said determined orientation or to have said determined orientation and said determined position with respect to the selected one object, so that said second image data capturing device is directed to a characterizing portion of the object; and wherein

said processor detects three-dimensional position and/or posture of the selected one object based on three-dimensional position of said characterizing portion obtained by said second image capturing device.

8. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 6, wherein said first image data capturing device is used as said second image data capturing device.

9. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 6, wherein said second image capturing device comprises a three-dimensional visual sensor of spot-light scanning type capable of measuring distance between the sensor and an object.

10. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 6, wherein said second image data capturing device comprises a structured-light unit for irradiating a structured light on the selected object and capturing an image of the object including the irradiated light on the object.

11. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 7, wherein said robot operation is an operation of picking up the selected one object from the plurality of objects, some of which are overlapped with each other.

12. (PREVIOUSLY PRESENTED) A robot system having an image processing function for determining orientation, or orientation and position of a robot operation on one of a plurality of objects of plural kinds, where the orientation of the operation corresponds to a determined orientation of the one object, where the determined orientation is a rotational posture of the one object, the system comprising:

a robot;

a first image capturing device capturing image data of the plurality of objects containing respective images of the objects;

a memory storing reference models, each comprising images of each of different kinds of reference objects corresponding to images captured by said first image capturing device, and storing indicia of the kinds respectively associated with said reference models, and information of a different orientation of the robot with respect to each of the different images of the reference object of each kind, where the captured information of orientation comprises information of a

rotational posture of the reference object relative to the robot, each of said reference objects being one of the kinds of the plurality of objects or having a shape identical thereto; and

a processor to perform matching on the image data containing images of the plurality of objects captured by said first image capturing device with each of said reference models successfully to select one object having an image matched with one of said kinds of the reference models, and to determine orientation, or orientation and position of the robot operation, the determining based on the image of the selected one object, based on said one reference model, based on the indicia of the kind associated with said one reference model and the information of the orientation of the robot operation with respect to the reference object associated with said one reference model of said one kind.

13. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 12, wherein said reference models are obtained from a part of the image data of the reference object.

14. (ORIGINAL) A robot system having an image processing function according to claim 12, wherein said reference models are obtained by processing the image data of the reference object.

15. (ORIGINAL) A robot system having an image processing function according to claim 12, wherein said first image capturing device comprises a camera for capturing two-dimensional image data.

16. (ORIGINAL) A robot system having an image processing function according to claim 15, wherein said image data of the reference object are captured by said camera from a predetermined distance.

17. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 12, further comprising a second image capturing device, wherein

said robot situates said second image data capturing device to have said determined orientation or to have said determined orientation and said determined position with respect to the object, and wherein

said processor processes second image data captured by said second image capturing device to detect position and/or posture of the selected one object with respect to said second image data capturing device.

18. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 12, further comprising:

a second image capturing device for obtaining three-dimensional position; wherein

said robot situates said second image data capturing device to have said determined orientation or to have said determined orientation and said determined position with respect to the selected one object, so that said second image data capturing device is directed to a characterizing portion of the object; and wherein

said processor detects three-dimensional position and/or posture of the selected one object based on three-dimensional position of said characterizing portion obtained by said second image capturing device.

19. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 17, wherein said first image data capturing device is used as said second image data capturing device.

20. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 17, wherein said second image capturing device comprises a three-dimensional visual sensor of spot-light scanning type capable of measuring distance between the sensor and an object.

21. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 17, wherein said second image data capturing device comprises a structured-light unit for irradiating a structured light on the selected one object and capturing an image of the object including the irradiated light on the object.

22. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 18, wherein said robot operation is an operation of picking up the selected one object from the plurality of objects, some of which are overlapped with each other.

23. (PREVIOUSLY PRESENTED) A method for automatically determining an arrangement of a workpiece relative to a robot, where the determined arrangement comprises at least rotational posture arrangement of the workpiece relative to the robot, the method comprising:

storing reference images corresponding to images of the workpiece or an object so shaped (workpiece/object) and reference arrangement information indicating arrangements of the robot and workpiece/object relative to each other when the images were captured, the reference arrangements comprising rotational arrangements of the workpiece relative to the robot;

from a known arrangement of the robot, capturing a working image of the workpiece among a plurality of randomly arranged workpieces with an imaging device;

finding one of the reference images that matches the workpiece in the working image; and

determining an arrangement of the robot relative to the workpiece based on information indicating the known arrangement of the robot, and based on the reference arrangement information corresponding to the found reference image, where the determined arrangement comprises rotational arrangement of the workpiece relative to the robot.

24. (PREVIOUSLY PRESENTED) A method according to claim 23, wherein reference images and reference arrangement information is obtained for workpieces/objects of different shapes, and wherein the finding comprises first determining that a reference image of one of the different shapes matches the working image of the workpiece, and then finding one reference image of the shape that best matches the working image.

25. (PREVIOUSLY PRESENTED) A method according to claim 23, wherein the robot is used to capture the reference images, and wherein the reference arrangement information represents arrangements of the robot when capturing the reference images.

26. (PREVIOUSLY PRESENTED) A method according to claim 23, wherein a second imaging device is affixed to the robot and is used to determine additional arrangement information used to determine the known arrangement of the robot relative to the workpiece.

27. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 7, wherein said first image data capturing device is used as said second image data capturing device.

28. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 7, wherein said second image capturing device comprises a three-dimensional visual sensor of spot-light scanning type capable of measuring distance between the sensor and an object.

29. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 7, wherein said second image data capturing device comprises a structured-light unit for irradiating a structured light on an object and capturing an image of the object including the irradiated light on the object.

30. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 18, wherein said first image data capturing device is used as said second image data capturing device.

31. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 18, wherein said second image capturing device comprises a three-dimensional visual sensor of spot-light scanning type capable of measuring distance between the sensor and an object.

32. (PREVIOUSLY PRESENTED) A robot system having an image processing function according to claim 18, wherein said second image data capturing device comprises a structured-light unit for irradiating a structured light on an object and capturing an image of the object including the irradiated light on the object.

IX. EVIDENCE APPENDIX

Not applicable

X. RELATED PROCEEDING APPENDIX

Not applicable